

MOTIONS OF THE EARTH AND MOON

The Earth:

1. The earth "spins" on its axis which accounts for the day/night. The period of this day/night is 24 hours (by definition). The earth spins counterclockwise (as viewed above the north pole) which accounts for the sun rising in the east and setting in the west.
2. The earth "orbits" the sun which accounts (along with its tilt) for the seasons. The period of the earth's orbit is 365.242 days.
 - a) 365 days = 1 normal year;
 - b) leap year adds one day every four years, or $\frac{1}{4}$ day per year, or .25 days per year for a total of 365.25;
 - c) we subtract one day every century, or .01 days per year for a total of 365.24 [no leap year on years divisible by 100];
 - d) we add two days every 1000 years, or add one day every 500 years, or .002 days per year for a total of 365.242 [keep leap year on years divisible by 500].
3. The earth has a tilt of $23\frac{1}{2}^\circ$ which (along with its orbit) accounts for the seasons.
 - a) The tilt of the earth is thought to be changing between 22° and 24° . This is technically called "nutation". This may affect the appearance and disappearance of ice ages since a bigger angle will cause the seasons to be more extreme.
 - b) The tilt of the earth "wobbles" or more technically precesses in a clockwise manner so that the earth's seasons appear a little bit earlier (relative to the stars) each year. It takes about 26,000 years for the earth to precess once. Thus, it takes about 2000 years for the earth to precess far enough that the sun appears in a different constellation of the zodiac on the spring equinox. Also, Polaris (the North Star) now appears almost straight above the north pole, but it will not always be so since the axis will precess away from that alignment.
4. The earth moves not in a perfect circle, but in an ellipse (although close to a circle).
 - a) Perihelion is when the earth is closest to the sun; aphelion is when the earth is farthest from the sun.
 - b) The earth is actually closest to the sun on about Jan. 3. Since it moves close to a circle, this has little to do with the seasons.
 - c) However, it may contribute to the appearance and disappearance of the ice ages since the day of closest approach moves forward relative to the seasons very slowly (it rotates through the seasons with a period of about 115,000 years).

The Moon:

1. The moon "orbits" the earth with a synodic period (synodic means relative to the earth/sun rather than to the stars) of $29\frac{1}{2}$ days. Due to the orbiting of the earth around the sun, this is longer than the sidereal period which is 27.3 days.
2. The moon "spins" about its axis causing day/night on the moon with a period of $29\frac{1}{2}$ days (same as the period of its orbit about the earth). [Thus a "day" on the moon lasts about 15 earth days (i.e., 24 hours), and a "night" on the moon also lasts about 15 earth days.]
3. The moon's orbit is not a perfect circle but is in fact an ellipse. The point of closest approach to the earth is called perigee; the point farthest away is called apogee.
4. The moon's orbit is not along the ecliptic but is inclined $5\frac{1}{2}^\circ$ relative to the ecliptic. The intersection of the plane of the ecliptic with the plane of the moon's orbit defines a line called "the line of nodes".

Eclipses:

1. Because the basic alignment of the earth and moon,
 - a) solar eclipses can happen only near new moon, and
 - b) lunar eclipses can happen only near full moon.

 2. The "umbra" is the area behind an object that is totally in shadow. The penumbra is the area behind an object only partially in shadow.
 - a) The umbra for the earth extends 1,384,000 km behind it.
 - b) The umbra for the moon extends 373,400 km behind it.
 - c) The moon's distance from earth at perigee is 356,412 km; at apogee it 's 406,686 km.
 - (1) Since the earth's umbra extends much farther than the moon even at apogee, the moon can pass through the earth's shadow (umbra) regardless of apogee or perigee,
 - (2) But since the moon's umbra extends to a distance between the moon's perigee and apogee distance, the earth can pass through the moon's shadow (umbra) only near perigee [total solar eclipse only near perigee, otherwise partial or annular solar eclipse if near agogee].

 3. Because of the tilt of the moon's orbit from the ecliptic, its distance from the earth, and its own size, there can be eclipses only when the line of nodes is approximately lined up with the sun.
 - a) The "season for eclipses" is 31 days long for solar (including total, annular, and partial) eclipses where part of the earth goes through the moon's umbra. [Note: not all parts of the earth will see every solar eclipse. Total eclipses at any one spot on the earth are extremely rare!]
 - b) The "season for eclipses" is 24 days long for lunar eclipses where at least part of the moon goes through the earth's umbra. [This is shorter since the diameter of the earth's umbra is only .72 of the earth's diameter as it crosses the moon's orbit.]
 - c) Since the line of nodes slowly moves, the "season for eclipses" happens not simply twice a year - once every six months, but instead happens once every 5.8 months.
- RESULT: We can have 1 or 2 solar (including partial, annular, and total) solar eclipses once every 5.8 months, and we can have 0 or 1 lunar eclipse once every 5.8 months. Total solar eclipses happen somewhere on the earth only about once a year, and happen at any specific location very rarely.